Bloch Equation in the Rotating Frame, Multidimensional Excitation

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Overview

This lecture will cover the basic concepts needed to understand the theory and implementation of multi-dimensional RF pulses. The ideas of excitation k-space and the Fourier picture for small tip angle RF pulses will be covered in detail. The common k-space trajectories and pulse designs will be discussed. Examples of 2D and 3D spatially selective excitations as well as spectral spatial pulse designs will be presented. Applications including field inhomogeneity compensation and parallel transmission will be covered as well. Upon completion of the lecture, the audience should have a good fundamental understanding of multi-dimensional RF pulse design as well as possess a few tools to begin designing their own pulses.

Detailed Outline

1. The small tip angle approximation
    a. The Fourier picture and excitation k-space (1)
    b. Simple analytical designs
    c. Approximate least squares solution (2)
    d. Parallel transmission (3,4)
2. 2D and 3D k-space trajectories
    a. Spiral (5)
    b. Spectral spatial pulses(6)
    c. Spokes (7)
3. Applications multi-dimensional spatial excitations
    a. B1 inhomogeneity correction using a 3D slice-select pulse
    b. B0 homogeneity correction using spectral spatial pulses (8)
4. Simple Matlab programs (code provided by speaker)
    a. 2D spiral pulse
    b. Spectral spatial pulse
    c. Bloch equation simulator

References

1. Pauly JM, Nishimura D, Macovski A. A k-space analysis of small-tip-angle excitation. J Magn Reson 1989;81:43-56.
2. Yip CY, Fessler JA, Noll DC. Iterative RF pulse design for multidimensional, small-tip-angle selective excitation. Magn Reson Med 2005;54(4):908-917.
3. Katscher U, Bornert P, Leussler C, van den Brink J. Transmit SENSE. Magn Reson Med 2003;49(1):144-150.
4. Zhu Y. Parallel excitation with an array of transmit coils. Magn Reson Med 2004;51(4):775-784.
5. Hardy CJ, Cline HE. Spatial Localization in Two Dimensions using NMR designer pulses. Journal of magnetic resonance 1989;82(647-654).
6. Meyer CH, Pauly JM, Macovski A, Nishmura DG. Simultaneous spatial and spectral selective excitation. Magn Reson Med 1990;15:287-304.
7. Saekho S, Yip CY, Noll DC, Boada FE, Stenger VA. Fast-kz three-dimensional tailored radiofrequency pulse for reduced B1 inhomogeneity. Magn Reson Med 2006;55(4):719-724.
8. Yip CY, Yoon D, Olafsson V, Lee S, Grissom WA, Fessler JA, Noll DC. Spectral-spatial pulse design for through-plane phase precompensatory slice selection in T2*-weighted functional MRI. Magn Reson Med 2009;61(5):1137-1147.